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AUTHOR	Ozer, M. Naci; Bekir, Ahmet
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ABSTRACT

The purpose of this study is to give students and teaching staff in universities an understanding and a sense of pride in the aims and achievements of learning and teaching mathematics, and so help them explain or discuss these aims and achievements for all as well as students and colleagues. In addition, this study provides basic guidelines for students in creating a good image of mathematics and mathematicians, and tries to explain what mathematics is attempting to achieve and the problems faced in teaching mathematics in higher education. (Author)

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THOUGHTS ON THE TEACHING OF MATHEMATICS IN HIGHER EDUCATION: A CASE OF TURKEY

M.Naci ÖZER & Ahmet Bekir

Osmangazi University

E-mail: mnozer@ogu.edu.tr & abekir@ogu.edu.tr

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THOUGHTS ON THE TEACHING OF MATHEMATICS IN HIGHER EDUCATION: A CASE OF TURKEY

M.Naci ÖZER & Ahmet BEK_R

Osmangazi University, Turkey

Abstract: The purpose of this study is to give students and teaching staff in universities an understanding and a sense of pride in the aims and achievements of learning and teaching mathematics, and so help them explain or discuss these aims and achievements for all as well as students and colleagues. In addition, we would like to provide basic guidelines for students in creating a good image of mathematics and mathematicians and try to explain what we are attempting to achieve, and the problems we face in teaching mathematics in higher education

Introduction

Unlike other sciences, mathematics, or at least some parts of it is taught to all students from primary to higher education; this makes mathematics teaching and mathematics education so important. We teach mathematics to students who will be the future teachers and researcher of mathematics in universities and they must be well taught by qualified people.

Higher education in the Turkish educational system is similar to the other countries around the world and includes all education institutions offering at least two years of education after secondary education. Higher education institutions are universities, faculties, institutes, colleges, and conservatories, vocational colleges, application and research centers (Acat, Demirel and Turan 2002).

One simple reason for studying mathematics to an advanced level is that it is interesting and enjoyable. People like its challenge, its clarity, and the fact that you know when you are right. The solution of a problem has an excitement and a satisfaction. You will find all these aspects in a university degree course. However some people may think that mathematics is so much theoretical to understand.

Mathematics is about pattern and structure; it is about logical analysis, deduction, calculation within these patterns and structures. When patterns are found, often in widely different areas of science and technology, the mathematics of these patterns can be used to explain and control natural happenings and situations. Mathematics has a pervasive influence on our everyday lives, and contributes to the future social strengths and the wealth of the country.

Teachers and researcher of mathematics in mathematics education share a common goal "increasing students learning and understanding of mathematics" or "making mathematics accessible to all students" since all the students (or almost all) are eager to learn. According to Hiebert et al. (1998), understanding takes place when students develop relationships and connections in their mathematical knowledge. They also claimed that a key component of developing relational understanding is communication which involves talking, listening, writing demonstrating, watching,... participating in social interaction, sharing thoughts with others, listening to others share their ideas. Communication is also important in learning mathematics and developing mathematical understanding. The communication process also helps build meaning and permanence for ideas and makes them public. Teachers and researcher of Mathematics who emphasize learning mathematics by helping students effectively share ideas provide the foundation for communication in the mathematics class-room. Theoretical frameworks of teaching mathematics have often been derived from good teaching practice. As Zebroski suggested," Theory is not the opposite of the practice, but it is a supplement to practice. Theory is practice, a practice of a particular case."

We start with some general questions to which we believe it is helpful for students and colleagues to be able to formulate some kind of answers. The primary motivation for possible answers to some of these questions, such as those given or suggested here, is the Brown & Porter's paper "*The methodology of mathematics*" (1995b).

What is mathematics?

The definition of mathematics changes corresponding with each generation and each thoughtful mathematician within a generation formulates a definition according to his lights. Thus we only give a naive definition, adequate for the dictionary and for an initial understanding, is that *mathematics is the science of quantity and space*. This

definition can also be expanded a bit, one might add that *mathematics also deals with the symbolism relating to quantity and to space* (Davis and Hersh 1981).

What is the importance of mathematics?

It is not generally recognised how much of a part mathematics plays in our daily lives. Some of the mathematics is of course quite old: every day we use numbers, graphs, addition and multiplication. It is easy to forget that the invention of these was at one time a great discovery. For example, the replacement of Roman numerals by Arabic numerals. A key aspect of the Arabic system is its use of the number zero. At first it seems absurd to count the number of objects in an empty box. The surprise is how essential this is for an adequate numeration system, in which the number 0 is used as a place marker. The lack of this concept of zero held up the progress of mathematics for centuries.

Without the mathematics of cryptography, there would not be possible the current level of electronic financial transactions crossing the world, and involving billions of dollars. Currently, the mathematics of category theory, a theory of mathematical structures, is being used to give new insights into future logics and algebras for the design of the next generation of programs and software.

The enormous applications of mathematics in engineering, in statistics, in physics, are common knowledge. It is also imagined that the role of mathematics is being taken over by the use of supercomputers. It is not so generally realised that these supercomputers are the servants of mathematical and conceptual formulations: the electronics is marvellous in that it does the calculations so quickly and accurately. For example, body scanners are an application, a realisation, of a piece of 19^{th} century mathematics expressing how to reconstruct a solid object of varying density from views through it of an X-ray, where the only measurement is the change of intensity as the ray passes through the body, for a large number of varying positions of the ray. The theories of the big bang, of fundamental particles, would not be possible without mathematics.

What is the nature of mathematics?

There is here a mystery. The Nobel prize-winner E. Wigner has written a famous essay "The unreasonable effectiveness of mathematics in the natural sciences" (Wigner

1960). For us, the key word is "unreasonable". He is talking about the surprise that the use of mathematics is able to give predictions which are in accord with experiment to the extent of nine significant figures. How is such astonishing accuracy possible?

It seems likely that a full "explanation" of the success of mathematics would need more understanding of language, of psychology, of the structure of the brain and its action, than is at present conceivable. Even worse, the development of such understanding might need, indeed must need, a new kind and type of mathematics. It is still important to analyse the scope and limitations of mathematics. It is also reasonable that such an analysis should be a necessary part of the education and assessment of a student of mathematics. Of what use is a student who does not know such things?

Here then are some quotations from this article:

... that the enormous usefulness of mathematics in the physical sciences is something bordering on the mysterious, and that there is no rational explanation for it.

Mathematics is the science of skilful operations with concepts and rules invented just for this purpose. [this purpose being the skilful operation ....]

The principal emphasis is on the invention of concepts.

The depth of thought which goes into the formation of mathematical concepts is later justified by the skill with which these concepts are used.

The statement that the laws of nature are written in the language of mathematics was properly made three hundred years ago; [it is attributed to Gallileo] it is now more true than ever before.

The observation which comes closest to an explanation for the mathematical concepts' cropping up in physics which I know is Einstein's statement that the only physical theories which we are willing to accept are the beautiful ones. It stands to argue that the concepts of mathematics, which invite the exercise of so much wit, have the quality of beauty. In order to discuss this, it is of interest to compare mathematics with other subjects, and to link this with the question of the objects of study of a subject, and of its importance.

Suppose we ask questions of a few of our fellow scientists as to why one should study their subject. According to Porter and Brown, 1995, answers might run as follows:

The astronomer: In astronomy we study the beginnings of the universe, and the flow of time over billions of years, as well as the furthest distances of space. What could be more enthralling? We have some money for this study, with various telescopes over the world, but of course not enough.

The physicist: In physics, we study the fundamental constituents of matter. What could be more fascinating? Without physics, there would be no astronomy, for example. Thus many more of the best students should study physics, and the Government should give us a lot of money.

The chemist: In chemistry, we make molecules do things for us, so that chemistry is part of our everyday lives. Without the understanding found by chemistry, there would no study of the stars, and no understanding of biology, of the formation of the planets. So, many of the brightest students should study chemistry, and the Government should give us a lot more money.

The biologist: Biology is about life. What is life? How did it come about? How does it interact with us and the world? We are all concerned with life. So, many more students should study biology, and the Government should give us a lot more money.

The engineer: Engineering is about making things which control our environment and do things for us. Without engineering, modern civilisation is inconceivable. Many more students should study engineering, and the Government should give us a lot more money.

The mathematician: Mathematics is about the study of pattern and structure, and the logical analysis and calculation with patterns and structures. In our search for understanding of the world, driven by the need for survival, and simply for the wish to know what is there, and to make sense of it, we need a science of structure, in the abstract, and a method of knowing what is true, and what is interesting, for these structures. Thus mathematics in the end underlies and is necessary for all these other subjects. This is part of our claim for your attention, and for the support for our studies. Another part of this claim is the fascination and wonder at the new patterns and structures, the surprising relationships, which our study has found. Mathematics also brings humility. We know how hard it can be to decide the truth of but one apparently simple and clear statement. We are aware of the limitations of mathematical truth, that not all that is true can be

proved. You will not find a mathematician writing that the final solution, the unified theory which will solve everything, is at hand. Rather, we are looking for the surprises which show us a new view of the world, and new riches to explore. Experience leads us to expect these to appear. For the mathematician, the world is not only stranger than you imagine, but stranger than you can now imagine. It is our job to investigate this strangeness.

What are the objects of study of mathematics?

This has already been answered to some extent. Mathematics does not study things, but the relations between things. A description of such a relation is what we mean by a "concept". Thus we talk about the distance between towns, and might feel this is less "real" than the towns themselves. Nonetheless, relations between things, and our understanding of these relations, is crucial for our operation in and interaction with the world. In this sense, mathematics has the form of a language. It must be supposed that our ability to operate with concepts, with relationships, had and maybe continues to have an evolutionary value.

It is also curious in this respect that the achievements of mathematics are generally held by mathematicians to be the solution of some famous problem. Certainly such a solution will bring to the solver fame and fortune, or at any rate a certain fame within the world of mathematicians. Yet the history of mathematics and its applications shows that it is the language, methods and concepts of mathematics which bring its lasting value and everyday use. We have earlier mentioned some examples of this. At a more advanced level, we can say that without this language, for example that of groups and of Hilbert spaces, fundamental particle physics would be inconceivable.

Some of the great concepts which have been given rigorous treatments through this mathematicisation are: number, length, area, volume, rate of change, randomness, computation and computability, symmetry, motion, force, energy, curvature, space, continuity, infinity, deduction. Very often the problem to make some mathematics is, in the words of a master of new concepts, or "to bring new concepts out of the dark" . It is

these new concepts that make the difficult easy, which show us what has to be done, which lead the way.

More important is the way mathematics deals with and defines concepts, by combining them into mathematical structures. These structures, these patterns, show the relations between concepts and their structural behaviour. As said before, the objects of study of mathematics are patterns and structures. These patterns and structures are abstract, a notion discussed below.

What is the methodology of mathematics?

Here again is a subject which is rarely and not widely studied. There is the comment of Paul Erd"s that mathematics is a means of turning coffee into theorems. Perhaps, though, this does not help the beginner too much. So let us look at some of the issues discussed in the book by Davis and Hersh, (1981), "The mathematical experience", particularly the section of the first book on "Inner issues". This deals with a number of themes.

(i) Symbols

The use of symbols and symbolic notations is one of the characteristics of mathematics, and one which puts off the general public. People will say they were able to do mathematics till it got onto x and y. The manipulation of symbols according to rules is still an important part of the craft of mathematics. We find we have to teach people who wish to master say economics but who are unable to deduce from $x - 2 = 4$ that $x = 6$. This makes very difficult the understanding of the concepts of economics. Very complicated relations can be expressed symbolically in a way which can hardly be conveyed in words. This economy which symbols allow is improving continually, as the symbols are used in the denotation of advanced concepts and the rules of the symbol manipulation are used to model the rules for the concepts.

It has been said, in an exaggerated way, that the history of mathematics is the history of improved notation. This reflects the finite nature of intelligence, which requires props and metaphors to help and guide it.

Some symbols are in themselves metaphors. Examples are =, < . <, \le, \subseteq, \to, \angle, \int, $ and so on. Others have acquired strong associations, so that we can use them as metaphors. The use of particular symbols is something that changes with time, as mathematicians become accustomed and find appropriate a new notation.

In some cases, a notation, brought about by the laziness of mathematicians, leads to a new theory. For example, system of linear first order differential equations of the type

$$a_{11}\frac{dx_1}{dt} + \ldots + a_{1n}\frac{dx_n}{dt} = 0, \ \ldots, a_{m1}\frac{dx_1}{dt} + \ldots + a_{mn}\frac{dx_n}{dt} = 0,$$

get abbreviated over time to $\mathbf{A}\frac{dx}{dt} = \mathbf{0}$, which you can see is simpler to write without understanding what the displayed line means. In order to allow for the correct manipulation of this abbreviation it turns out that the rules for what are called matrices were worked out, and these are widely used in mathematics, science and engineering.

(ii) Abstraction

This is an essential part of mathematics, and again is one part of what makes mathematics incomprehensible to the general public.

As said above, mathematical structures are abstract. They are defined by the relations within them. They are thought of as non-sensual. The advantages of abstraction are at least threefold.

An abstract theory codifies our knowledge about a number of examples, and so makes it easier to learn their common features. Only one theory is needed, to replace a multiplicity. This codification exploits analogies, not between things themselves, but between the behaviour and relations of things. Finding these analogies, the abstract theory which replaces a multiplicity, is an important method in mathematics.

Once the theory is available, it may be found to apply to new examples. This leads to the excitement and joy of "That reminds me of ...!". For this new example, a body of established theory is available, at the turn of a page.

An abstract theory allows for simpler proofs. This is a surprise, but is commonly found to be true. The abstract theory allows for the distillation of essentials. It is of

interest to know if a theorem or fact is true in the general situation or only in the particular example. The abstract theory allows for the removal of possibly irrelevant aspects.

(iii) Generalisation and extension

This has some features in common with abstraction, but usually applies differently. Thus a generalisation of the (3,4,5) right angled triangle is Pythagoras' Theorem, while an extension is Fermat's Last Theorem, which says that the equation $x^n + y^n = z^n$ has no solutions for positive integers x,y,z if $n>2$. This was thought recently to have been settled, but it seems there is still a gap in the proof. (This gap has now been filled.)

(iv) Proof

The rigorousness of the notion of proof is a particular feature of mathematics. It is why mathematics is essential in engineering, safety, physics and so on.

The notion of proof, of validity, in mathematics, is an aspect of the general question: What is the notion of validity in an area of study? Each area, from social sciences, economics, chemistry, biology, education, law, literature, and so on, has its notion of validity, and the contrast and uses of this notion are of particular interest.
The question of what is acceptable as a valid argument in mathematics is still subject to argument and discussion, particularly with the existence of very long proofs, and with the use of computers for visualisation, experimentation, and calculation.

(v) Existence of mathematical objects

A great mathematician has urged that the major problem of mathematical education is to teach the reality of mathematical objects. What is this reality? In what way do these objects exist? This question has been a matter of major interest to many philosophers of mathematics, but its interest is perhaps in the process of being downgraded. Mathematics is often about processes. The question of existence of a mathematical structure is maybe like asking whether the game of chess exists. Clearly it does not exist in the way that tables and chairs exist, but none the less, it influences many

lives, and passes the cash test. (Does it earn money? The answer is clearly: Yes, for some, for example world champions and makers of chess equipment.)

The relation of mathematical concepts and methods to processes is indicated by the way that memory of muscular action and rhythm are important aspects of mathematical work. A lot of mathematics is concerned with the realisation and understanding of the effect of repetitive processes and methods. Mathematicians are good at understanding and imagining moving things around, such as from one side of an equation to another, or changing a pattern in space. They use movements of their hands and arms to convey what is happening. The objects and ideas of which mathematicians talk are sometimes a kind of concatenation of a variety of such remembered processes. The representation of these ideas in writing is by contrast often bare and sparse, and this is part of the difficulty of learning the use and application of these objects and ideas. On the other hand, it also allows for each person to make the interpretation and internalisation most appropriate to themselves.

(vi) Infinity

The taming of the infinite, or the enlargement of the imagination to include infinite operations, is one of the joys of mathematics, and also one of the scandals. Are these infinite objects real? The surprise is that these infinite, possibly unreal, objects can be used to prove finite real things, and this again is an aspect of the mystery of the subject. Suppose for example that these infinite objects are used to prove the safety of a nuclear installation, or of an aircraft landing system? What credence should be placed on such a proof? These are real issues.

Is there research going on in mathematics?

Those who wish a practical test should look at the change in Mathematical Reviews since it was started in 1940. This monthly journal contains abstracts of mathematical papers. Roughly speaking, a few paragraphs are enough for a five page paper. The growth in terms of numbers of pages over these years is about eleven times. Each month now there are published about 400 large pages of abstracts of mathematical papers. This is indeed the golden age of mathematics, both in quantity and quality.

The aims of this research are at various levels. One is the advancement in knowledge about particular types of structures, which are already well defined. Another is the introduction of the study of new structures, as they have appeared and been shown to be relevant. There are new relations between structures. There is the urge to simplification, to find structures which explain structures, and help us to understand the way particular structures behave in themselves and relate to other structures.

What is difficult for the newcomer in the field, and for the general public, to understand is how one goes about doing mathematical research. Here we give some pointers, by suggesting four ways of going about the job, of intention. There are certainly many more, and each individual researcher must in the end devise his or her own strategy for success. It is also difficult to know how much one must know before starting on mathematical research. A famous answer to this particular question was: "Everything or nothing."

Method 1: Apply a standard method to a standard type of problem.

This has every guarantee of success, provided one is sufficiently skilful in the standard method. This method is probably a part of every successful research project. Indeed, a common method of mathematical research is to reduce a problem to one already considered. If the original problem is too difficult, then a standard strategy is to simplify the problem so that it does become of standard type, before adding the complications which make it a new problem. The general presumption might be that one can only do easy things. So the method is to reduce a problem to a type that can be seen to be easy. If in doubt, do the obvious thing first.

Those who practice and become skilful at applying standard methods, may someday find that their skills apply to a problem no one else has considered, and that this leads to new and important results.

Much of the education of a mathematician is concerned with acquiring the skills and knowledge appropriate to work in a chosen area.

Method 2: Attacking a famous problem at the frontiers of knowledge

This is the strategy of going for a famous problems at a peak of knowledge. The advantage is that if you succeed, then you will become famous. It is more difficult to assess your chances of success. You will probably need some new ideas. This seems to be the most ambitious method for a young person.

Usually, though, one attacks smaller problems at the frontiers of knowledge, problems to which not so much effort has been devoted, and so where there is a greater likelihood of success. You will almost certainly have to study to find what has been done, what techniques are available, and which you need to master.

It is helpful to have problems for which the criteria for success are clear: the answer is yes or no to some question. On the other hand, failure to provide a solution is also clear cut, as is finding the problem too easy. Mathematicians need to build into their strategy plans for dealing with both too little and too much success on the problem at hand.

Method 3: Relate different areas of knowledge

In this method you learn about the beginnings of different areas, and find relations between them. So you fill in the gaps between the peaks, while often the "top people" are occupied with building up the peaks. The advantages of this method are that you learn something of different areas, and in a useful way, since you have to work to do the translations between the two areas. This is a good method for PhD theses, since a supervisor can often see the relation without having worked out the details. It also advances the general unity of mathematics. Another advantage is that it gets you used to the idea of proving small but useful results which help to fill in the gaps and create the picture of what is going on.

Method 4: Blue sky research

Here you have some idea of a mathematics which ought to exist, and the characteristics of it. You also have a few hints as to the kind of materials of which the mathematics ought to be made. The problem is that proper mathematics requires definitions, examples, propositions, theorems, proofs, calculations, and in the beginning none of these exist. So they have to be assembled over a period of time. In what order

should this be done, and how important will the work be? This can hardly be judged till the theory is worked out, and such a theory does not emerge, like Venus Anadyamene, fully formed from the sea. A theory accumulates in a journey over a period of years, and a gut feeling of importance of a line of investigation is necessary to motivate travel on a long road.

It has to be said that, paradoxically, the secret of success in research is the successful management of failure. For if you never fail, then it is likely that the tasks you have set yourself are simply too easy. Interesting research must have an element of risk. You need strategies for dealing with situations when things go wrong: the problem may have proved too hard, or too easy. What comes next? The analysis of the reasons for failure, and the comparison of these reasons for failure with the reasons for wanting to do this problem in the first place, becomes instructive for future work.

What is good mathematics?

We would not like to attempt to give any final answer to this, but all of us should try and formulate some of the aspects that we are looking for. For a new mathematical paper we ask: Are the results new? How far ahead do they go of the current literature? Is the paper clear and well written? Is there a clear familiarity by the author with current work in the field, and the relation of his or her results to the field? How surprising are the results? How elegant are the methods? Are there any new methods introduced?

Some of what we call the best mathematics is that which introduces new ideas and concepts which make the previously difficult easy. This contradicts an impression you may have that mathematics is meant to be hard, and is good for you partly for that reason, like a cold bath. To the contrary, good mathematics can, perhaps should, be easy. It is just that often we do not know how to do this. The combination of apparently simple arguments with a surprising conclusion, perhaps with a surprising twist, is what we like best of all.

What is worrying is that many young mathematicians go through their education without the notion of "good mathematics" even being debated. Yet for any human activity, there is always the question of its value, both for society and personally. There is an argument that the teaching of a subject should reflect something of the values of the

professionals in it. For example, for a professional, it is not enough just to produce an answer, but it is important also to produce if possible a satisfying explanation.

What is the role of mathematicians?

Mathematicians must be qualified to help students learn mathematics well and make use of their strong points--their attentiveness in listening to lectures, their good memory and ability to memorize, analyze and solve problems, and their conscientious completion of homework. We should guide them in class so that they grasp the content of the lectures, understand the derivation of the theorems and formulas, comprehend the reasoning, and then commit them to memory on the basis of fully comprehending the relevant concepts. Teaching staff in the mathematics department of our university make it a habit of having students collectively declaim the theorems after they have understood them and then memorize the theorems and formulas. Then, on the premise that students have understood and memorized such basic knowledge, they ask the students to practice repeatedly until they become proficient at using it. Although girls who come to the university begin with a relatively low starting point in ***mathematics***, after two or three years of solid basic training and of giving play to their strong points (willingness to listen and understand the professors derivation of theorems and formulas; willingness to memorize the theorems and formulas they learn; and willingness to practice over and over again until they have established a solid foundation), all of them show varying degrees of improvement.

Students especially girls have another strong point--they are sympathetic, love the collective, and help one another. Professors make use of this strong point to initiate one-on-one assistance in their classes. Students with good performances are made to understand that helping others will promote in themselves a deeper understanding and greater mastery of their knowledge, and they will also learn to sum up and use that knowledge. After one or two years of such efforts, those students who are the helpers have mastered relatively good study methods and developed an interest in learning ***mathematics***, while students who have been helped have made up for their shortcomings and gradually improved their performances. They had been carrying out one-on-one assistance in a lively manner.

In the course of ***teaching***, students must be made to understand the purpose of learning, classroom instruction must be combined with student realities, and students must understand what is being taught. Mathematics Professors should accomplish all these matters. It is also necessary to cultivate top-notch students, to develop math bellwethers in the class, and to develop an atmosphere in class in which students enjoy math. One important way of cultivating students' abilities is by doing mathematical proofs, but it is a common and natural phenomenon that students are afraid of ***mathematics***, and thus students most fear geometry. In the lecture, students have persisted in a "one-problem-per-week" program of practicing geometrical proofs. With the Professor's support, the class representative has conducted the one-problem-per week program in a lively manner. Every week, the Professors tacks up a particular way of thinking to solve the problem of the week, guides the students in resolving the problem by different approaches, and commends students who take an active part in the program. Encouraged by professors, students gather in small groups to explore regularities for solving problems. The program has gradually attracted more and more students; they have come to like ***mathematics***, and their ability to analyze and solve problems has improved.

It is also mathematicians' prerogative to write more popular and understandable books for helping students outside of the class. It is our duty to convince media, journalist to show and speak about our discoveries, to describe our community and may be to reveal our history. It is our responsibility to ask publishers to reprint the writings of famous mathematicians. It is our job to join international conferences and visit schools and different universities in order to lecture and give seminars on our own research, thus illustrating how lively our field is. This can be done, but there is only one recipe and one only: **MONEY**.

Conclusion

We conclude by following Brown and Porter (1995ab). There is a view that there is no more basic mathematics to be found. This view is comparable to the view of those who have said that physics was ended, the basic problems having been solved. On the contrary mathematics is undergoing a revolution, a quiet one, but a revolution none the less. This is occurring on two fronts.

There is first the computational revolution. For computation with numbers, or for graphics presentation, this revolution is well known. Less well known publicly is the computer software which can manipulate symbols and axioms, and other software which can carry out automated reasoning. In principle, these should give mathematicians power to calculate and reason a millionfold more than they can at present, and to deal with the complexities of systems thought previously to be intractable. The prospective effect of these on the teaching of mathematics has yet to be properly understood and assessed, although a lot of work is in progress. The effect on research has already been considerable and is likely to grow in its influence.

One of the pleasures of mathematics is the way it operates on various levels, which then interact. So the algebraic study of mathematical structures has itself led to new mathematical structures. Some of these structures have had notable applications in mathematics and in physics.

Nevertheless, there are still many current dangers for mathematics. There is a general lack of appreciation of what mathematicians have accomplished, and the importance of mathematics. Some of this has come about through mathematicians themselves failing to define and explain their subject in a global sense to their students, to the public, and to government and industry. It is possible for a student to get a good degree in mathematics without any awareness that research is going on in the subject.

Another danger is the growing reliance on computers as a black box to give the answer, without understanding of the processes involved, or of the concepts which are intended to be manipulated. So both the scope and the limitations of the computer fail to be understood, the mathematical basis is neglected and perhaps fails to be developed, and the computer may be used in ways which are inappropriate, or simply limited by the software design. It is said that some engineering firms are dispensing with their mathematical research departments in favour of engineers manipulating software packages. Will this ensure the safety or reliability of the product, and will it allow the use of the most advanced mathematical concepts? If these dangers are to be averted, then an increased understanding and appreciation of the questions with which we started are essential.

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